Distribution of Black-footed Albatross, *Diomedea nigripes*, off the West Coast of North America, 1949 and 1950[1]

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Since the oceanographic surveys of the California Cooperative Sardine Research Program began in March 1949, records have been kept of the numbers of albatrosses seen at each station. At monthly intervals the ships have covered an area approximately 1,300 miles long by 400 miles wide. The patterns of stations occupied, differing somewhat from cruise to cruise, and altered considerably in 1950, have been figured by McHugh (1950), Anonymous (1950), and McHugh and Ahlstrom (1951).

These albatross observations have formed a part of the objective, conceived early in the development of the research program, to study as many phases of the biology of the region as possible. Felin and Marr (1951) already have pointed out the importance of these subsidiary investigations in relation to the main purpose of the sardine program.

INDICES OF ABUNDANCE

Usually, counts were made shortly after the ship hove to at each station, and again just before departure. The second count commonly, but not always, exceeded the first (McHugh, 1950). The indices of abundance used here are based on the maximum numbers of birds observed at each station. For obvious reasons, no record was made at stations occupied during darkness, although albatrosses sometimes were seen at night (McHugh, 1952).

It is believed that several factors other than relative abundance may influence the counts. Birds may follow a ship as it cruises between stations, but it is not believed that the Black-footed Albatross travels great distances in this way (Miller, 1942; Thompson, 1951). The tendency to congregate about the motionless vessel may vary with weather conditions, especially if the frequency and duration of soaring flight is related to wind force, although an attempt to analyse the data along these lines produced no clear-cut relationship. Furthermore, counts may tend to increase during the day (McHugh, 1950) or when the ship is in an area for longer periods (Yocom, 1947). The visual acuity of birds and observers is affected almost certainly by atmospheric conditions and wind. The many observers undoubtedly varied in interest and in acuteness of vision. For these reasons, counts at adjacent stations were averaged by dividing the survey area into 21 blocks, by a grid of three blocks east to west and seven north to south (Fig. 1). These blocks are not equal in area, for the species seldom approaches within sight of shore, and often is not present in great numbers at the inshore stations. To avoid masking the reduced abundance near shore, the seven inshore blocks were chosen as far as possible to in-

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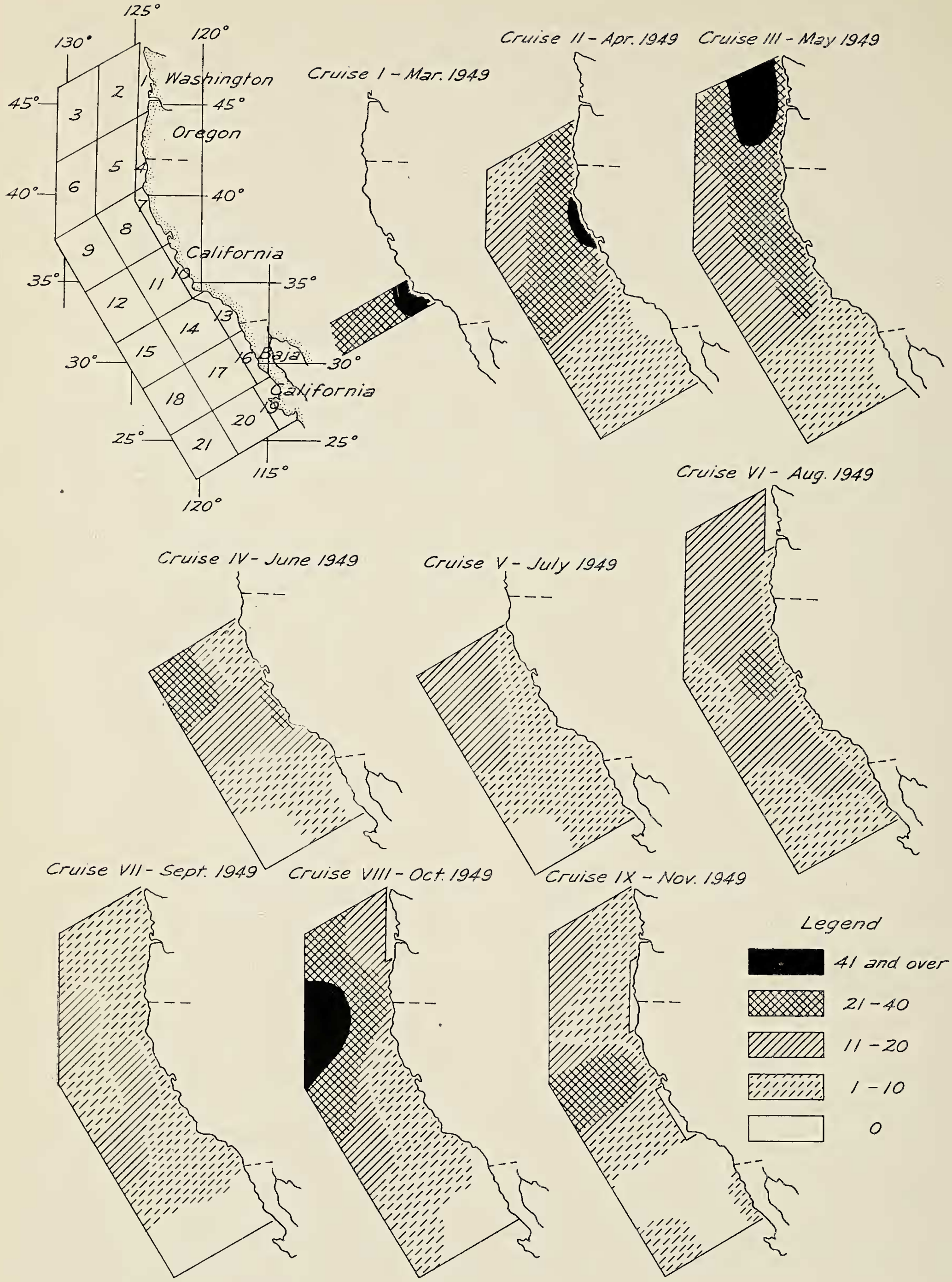

FIG. 1. Locations and numbers of blocks from which indices of albatross abundance were derived in 1949 and 1950 (upper left), and distribution of Black-footed Albatrosses over the survey area during 1949. The contours were drawn according to the average numbers of birds per station in each block.

clude only the inshore stations on each line. Their offshore limit is a line running roughly parallel to the coast about 40 nautical miles westward of the major promontories. The second series of blocks extends from the western boundary of the first and has a width of about 160 miles east to west; the third is approximately equal in width to the second. Each of the seven inshore blocks, about 9,600 square nautical miles, is roughly one-quarter the average area of the remainder. The inshore blocks each contained two stations in 1949, and an average of six in 1950; each offshore block contained an average of nine stations in each year.

As a monthly index of abundance, all counts within each block were averaged, a process designed to minimize many of the most serious sources of error. These indices may be defined as representing the best available estimate of relative monthly abundance within each block. There is little point in expanding these estimates into a measure of the total number of birds present in the area, for there is no adequate basis for determining the absolute density of birds per unit area that each count represents. Assuming, however, that all birds within a ten-mile square collect around the ship while it occupies a station, the total number of Black-footed Albatrosses present within the region surveyed in May 1949, the month in which most birds were observed, was close to 100,000. This estimate is not inconsistent with the results of the census made by Fisher (1949) on the Island of Midway.

The cruises have not always covered the entire region included within the station pattern. Sometimes parts of the area have been missed on account of adverse weather conditions or mechanical breakdowns. Sometimes the station coverage has been shifted according to plan, in response to seasonal changes in the location of sardine spawning. Blocks 7 to 18 inclusive were occupied on most cruises in 1949 and 1950, and it is possible to calculate an index of abundance for the waters off the California coast by summing the indices for these blocks (Table 1). However, it would be advantageous to discover a more restricted area that would reflect the abundance of birds equally well. Block 11 was chosen because it is sufficiently far north to contain relatively large numbers of albatrosses, yet close enough to an important sardine spawning area that it may be expected to be traversed on most, if not all, cruises. A high and statistically significant coefficient of correlation was obtained between the monthly indices for block 11 and for the larger area exclusive of block 11 ($r = +0.863$, P much less than 0.01). In view of the many possible sources of error to which these indices are subject, it is concluded that the relative abundance of birds in block 11, lying west of Point Conception, is indicative of the relative abundance off the entire California coast.

TABLE 1

Indices of Abundance of Black-footed Albatrosses in the Region Covered by Blocks 7 to 18 Inclusive

MONTHS	INDICES OF ABUNDANCE	
	1949	1950
February	...	63
March	...	113
April	132	66
May	106	74
June	86	87
July	60	62
August	78	61
September	46	25
October	66	...
November	59	...

GENERAL DISTRIBUTION

Thompson (1951) has observed *Diomedea nigripes* as far south as 15° 40′ N. in the Central Pacific. Along the west coast of North America, however, the species has never been observed in great abundance south of Cedros Island, off the coast of Baja California. Al-

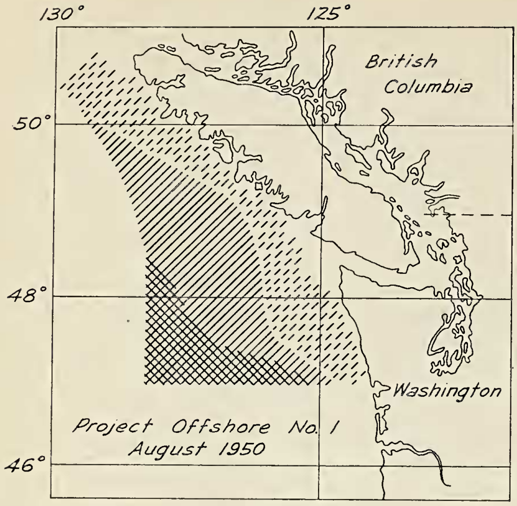

FIG. 2. Distribution of Black-footed Albatrosses off the British Columbia and Washington coasts in August 1950. Legend as in Figs. 1 and 3. The contours were drawn according to the numbers of birds at each station.

though Cruise 20, in November 1950, extended the coverage southward almost to 20° N., no albatrosses were seen at this time off the entire Baja California coast. Later cruises, reaching this latitude in all seasons, may be expected to define more accurately the southern extent of the species range.

To the northward, the Black-footed Albatross is common off British Columbia and Alaska, and has been seen irregularly in the Bering Sea (Kenyon, 1950). Counts supplied through the cooperation of Dr. J. L. Hart and R. J. Waldie from off the coasts of Washington and British Columbia in August 1950 range from 1 to 24, and average 13 birds per station (Fig. 2).

To the westward, in 1949 and 1950 only one cruise extended more than about 400 miles offshore. On this cruise, numbered 18, in September 1950, the maximum count in the region outside the grid defined in Figure 1 was six birds at station 70.220. *Diomedea nigripes* is found across the entire Pacific, however, for it breeds in the mid-Pacific islands in winter and spreads over the north Pacific at other seasons.

SEASONAL DISTRIBUTION AND ABUNDANCE

In 1949 and 1950 Black-footed Albatrosses were about twice as abundant in the survey area over the period March to May as in any other month. The distribution of counts in 1949 (Fig. 1) suggests that the decrease in abundance in the summer months is caused by a general northerly migration, for the greatest density of birds was encountered off Point Conception in March, off San Francisco in April, and off the Columbia River in May, an average northward shift of about 300 nautical miles per month. Not until October did similar concentrations appear again within the survey area, this time in a region well offshore from Cape Mendocino. In 1949 also, there appeared to be a general shift of the population from inshore in spring to offshore in fall.

In 1950 (Fig. 3) there were less definite indications of a progressive northerly migration, although the index of abundance was highest in March. If a northward movement did take place, it probably occurred earlier than in 1949, and there is some evidence that the return movement began in May, for the birds were more abundant off Cape Blanco in May, and off San Francisco in June than at any other period in 1950. Furthermore, in July and August the greatest densities were observed in the region between San Francisco and Point Conception. The 1950 season differed from 1949 also in that, from May to August inclusive, more birds were seen inshore and less at the offshore stations.

FACTORS AFFECTING ALBATROSS DISTRIBUTION

Variations in the numbers of *Diomedea nigripes* observed off the shores of North America have been attributed to various factors. Miller (1940) found these birds concentrated over a "cold tongue" of sea water, rich in nutrients and plankton. Thompson (1951) reported that the species was more abundant east of the 135th meridian, and showed that the increasing numbers of birds seen between

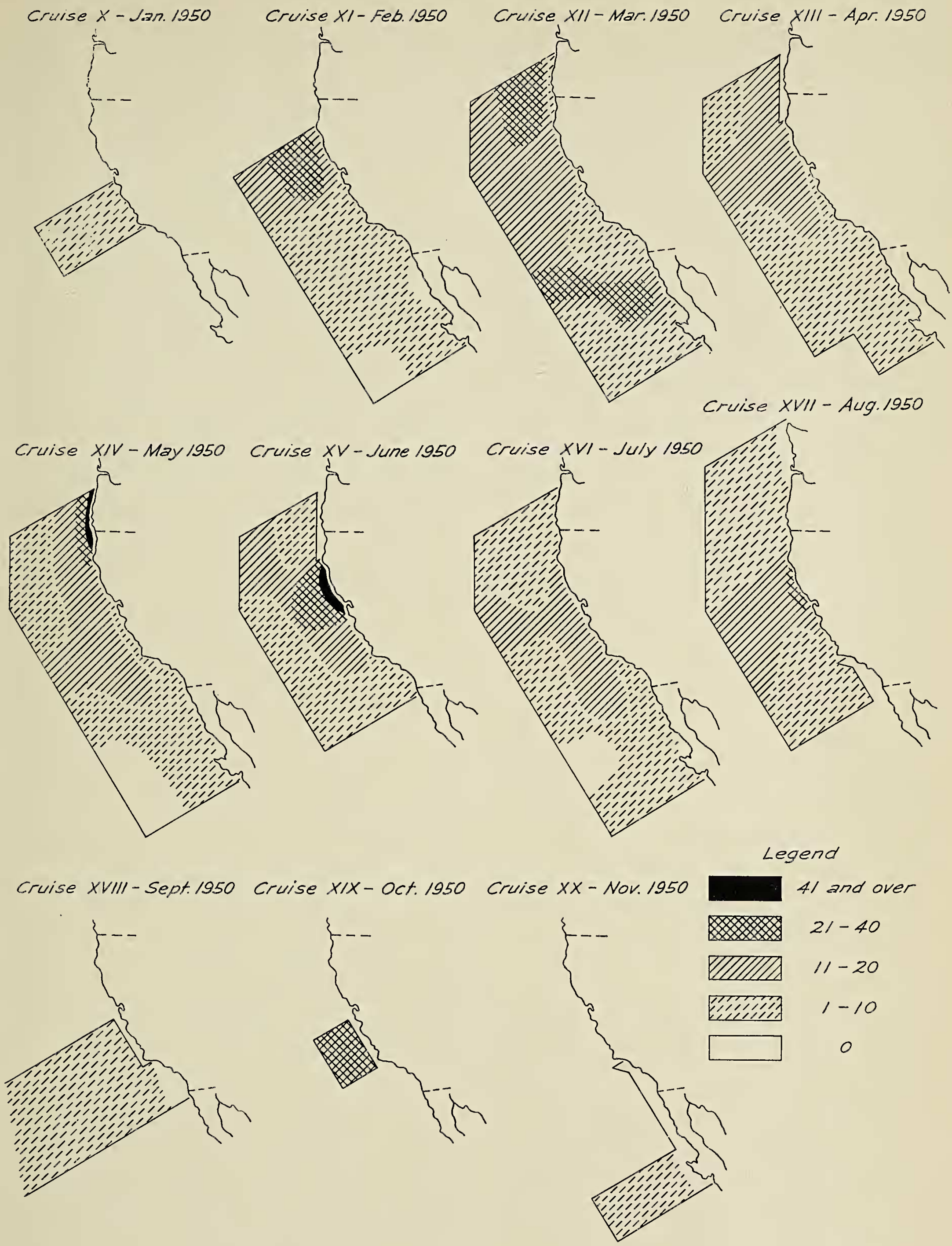

FIG. 3. Distribution of Black-footed Albatrosses over the survey area during 1950. The contours were drawn according to the average numbers of birds per station in each block.

TABLE 2
AVERAGE ALBATROSS COUNTS AND PLANKTON VOLUMES FOR CRUISES 1 TO 5

BLOCK NUMBERS	REGION	MEAN NUMBERS OF ALBATROSSES	MEAN VOLUMES OF PLANKTON
7–9	Northern Calif.	19	214
10–12	Central Calif.	20	141
13–15	Southern Calif.	4	65
16–18	Baja Calif.	2	48

this line and the coast were associated with decreasing sea temperatures. Thompson also noted a direct relationship between the numbers of jellyfishes, observed by luminescence in the ship's wake at night, and the numbers of albatrosses counted during the day. He reasoned that jellyfishes, and hence albatrosses, were most abundant in the colder, more productive waters.

No consistent relationship between the total plankton volume in a standardized net haul and the numbers of albatrosses seen at the same station was observed on the 1949 and 1950 cruises. In a general way, however, the blocks in which the highest average numbers of birds were recorded were those in which the greatest average plankton volumes occurred. As illustrated in Table 2, the numbers of albatrosses and the volumes of plankton per unit volume of water[3] were greatest off the northern California coast, and least off southern and Baja California. It is not known whether this association indicates a causal relationship.

It is tempting to search for relationships between the pattern of albatross abundance and the distribution of the various physical, chemical, and biological factors recorded at the hydrographic stations. The albatross counts presumably are not subject to the criticism that is levelled at counts of plankton and other marine organisms, namely, that they represent only the standing crop, for these birds are almost completely free from predation while at sea (Miller, 1940; Yocom, 1947; McHugh, 1952). Nevertheless, strong and apparently highly significant statistical correlations can be obtained even with random numbers by trial and error methods. Inasmuch as there is no good biological evidence to suggest that albatross abundance and any of the physical, chemical, or biological factors are related, no correlations were sought.

In former years, when it was more abundant, the Pacific sardine (*Sardinops caerulea*) performed an annual migration from California waters to summer feeding grounds off the Pacific Northwest, sometimes ranging as far north as southeastern Alaska. There is indirect evidence, particularly in the 1949 observations, that the Black-footed Albatross performs a similar seasonal migration northward along the coast. If such a migration does occur, it may be in response to similar stimuli. Continued study of the distribution and movements of these birds may provide valuable clues to the question of varying sardine abundance and availability.

SUMMARY

Counts of Black-footed Albatross were recorded at all stations occupied during daylight on cruises of the California Cooperative Sardine Research Program in 1949 and 1950. The survey area was divided into blocks, and the counts per station within each block were averaged to derive indices of abundance. Birds were most abundant off California and Baja California during the spring months, and

[3] The plankton volumes were taken from an unpublished mimeographed summary prepared by the staff of the South Pacific Investigations of the U. S. Fish and Wildlife Service.

higher counts were recorded in the northern part of the region. There is some evidence of a northward migration along the coast in summer, similar to the summer migration of the Pacific sardine.

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